recapitulate the principal physical conclusions which seem to be legitimately deducible from the whole investigation; in this recapitulation qualifications must necessarily be omitted or stated with great brevity.

When two meteorites are in collision, they are virtually highly elastic, although ordinary elasticity must be nearly inoperative.

A swarm of meteorites is analogous with a gas, and the laws governing gases may be applied to the discussion of its mechanical properties. This is true of the swarm from which the sun was formed, when it extended beyond the orbit of the planet Neptune.

When the swarm was very widely dispersed, the arrangement of density and of velocity of agitation of the meteorites was that of an isothermal-adiabatic sphere. Later in its history, when the swarm had contracted, it was probably throughout in convective equilibrium.

The actual mean velocity of the meteorites is determinable in a swarm of given mass, when expanded to a given extent.

The total energy of agitation in an isothermal-adiabatic sphere is half the potential energy lost in the concentration from a condition of infinite dispersion.

The half of the potential energy lost, which does not reappear as kinetic energy of agitation, is expended in volatilizing solid matter, and heating the gases produced on the impact of meteorites. The heat so generated is gradually lost by radiation.

The amount of heat generated per unit time and volume varies as the square of the quasi-hydrostatic pressure, and inversely as the mean velocity of agitation. The temperature of the gases volatilized probably varies by some law of the same nature.

The path of a meteorite is approximately straight, except when abruptly deflected by a collision with another. This ceases to be true at the outskirts of the swarm, where the collisions have become rare. The meteorites here describe orbits under gravity which are approximately elliptic, parabolic, and hyperbolic.

In this fringe to the swarm the distribution of density ceases to be that of a gas under gravity; and as we recede from the centre the density at first decreases more rapidly, and afterwards less rapidly than if the medium were a gas.

Throughout all the stages of its history there is a sort of evaporation by which the swarm very slowly loses in mass, but this loss is more or less counterbalanced by condensation. In the early stages the gain by condensation outbalances the loss by evaporation; they then equilibrate, and finally the evaporation may be greater than condensation.

Throughout the swarm the various meteorites are to some extent sorted according to size; as we recede from the centre the number of small ones preponderates more and more, and thus the mean mass continually diminishes with increasing distance. The loss by evaporation falls principally on the small meteorites.

A meteor swarm is subject to gaseous viscosity, which is greater the more widely diffused is the swarm. In consequence of this a widely extended swarm, if in rotation, will revolve like a rigid body without relative motion (other than agitation) of its parts.

Later in the history the viscosity will probably not suffice to secure uniformity of rotation, and the central portion will revolve more rapidly than the outside.

The kinetic theory of meteorites may be held to present a fair approximation to the truth in the earlier stages of the evolution of the system. But later, the majority of the meteors will have been absorbed by the central sun and its attendant planets, and amongst the meteors which remain free the relative motion of agitation must have been largely diminished. These free meteorites—the dust and refuse of the system—probably move in clouds, but with so little remaining motion of agitation that (except perhaps near the perihelion of very eccentric orbits) it would scarcely be permissible to treat the cloud as in any respect possessing the mechanical properties of a gas.

The value of this whole investigation will appear very different to different minds. To some it will stand condemned as altogether too speculative; others may think that it is better to risk error in the chance of winning truth. To me, at least, it appears that this line of thought flows in a true channel; that it may help to give a meaning to the observations of the spectroscopist; and that many interesting problems, here barely alluded to, may perhaps be solved with sufficient completeness to throw light on the evolution of nebulæ and planetary systems.

EDISON'S PERFECTED PHONOGRAPH.

THE marvellous results attained by Mr. Edison's recent improvement on, or, more properly perhaps, resurrection of, the original phonograph of 1878 have induced us to present a view of the latest form of the instrument, together with a short description of its main features and most recent performances.

Mr. Edison is still occupied in perfecting the instrument, and scarcely a week passes without his sending over to his European colleague, Colonel Gouraud, substantial evidences of progress towards perfecting the arrangements either for the recording and reproducing of all kinds of sounds, or else in the construction and the postal conveyance of phonograms.

Although, therefore, the instrument can hardly at present be said to have reached its final stage of development, in its chief constructive points it may be regarded as practically perfected; while some recent trials of it show that it is capable not merely of recording, but of reproducing, every kind of sound with which we are acquainted, including articulate speech, with a fidelity little short of absolute perfection.

When Léon Scott invented his phonautograph, he unconsciously came near the phonograph, though he merely contented himself with reproducing the vibrations pictorially on a blackened surface. Prof. Helmholtz, on the other hand, by his profound studies in the analysis and synthesis of speech into fundamentals, accompanied by varying combinations of subsidiary harmonics, seems to have created quite a scare among the phonographists, by showing them what a terribly complicated affair articulate speech was. In the phonograph, however, we have a machine which not only differentiates all these complicated systems of vibrations, checks, and harmonics, but integrates them equally well. It is, moreover, capable of repeating the integrations practically as often as we please.

This perfected power of record, reproduction, and preservation of sound has been accomplished partly through the substitution of a specially prepared wax for the original tinfoil, but also a good deal through other improvements in the diaphragms, needles, &c. The vibrations of the recording diaphragm are transferred by means of a cutting-needle to the wax, which is thus carved and indented into a series of hills and valleys, which represent in *intaglio* the resultant form of the original sound-vibrations, including part, if not all, of the minor inflections due to the presence of the subsidiary harmonics or overtones.

The tinfoil used in the original machine of 1878 only very partially fulfilled the office of a recording surface, and since every indentation in it necessarily involved a corresponding rise of the material on either side, the vibrations of the recording style, and *a fortiori* of the air itself, were only very imperfectly reproduced on its surface. The hollow character of the undulations, moreover, caused them to be easily effaced after a few repetitions.

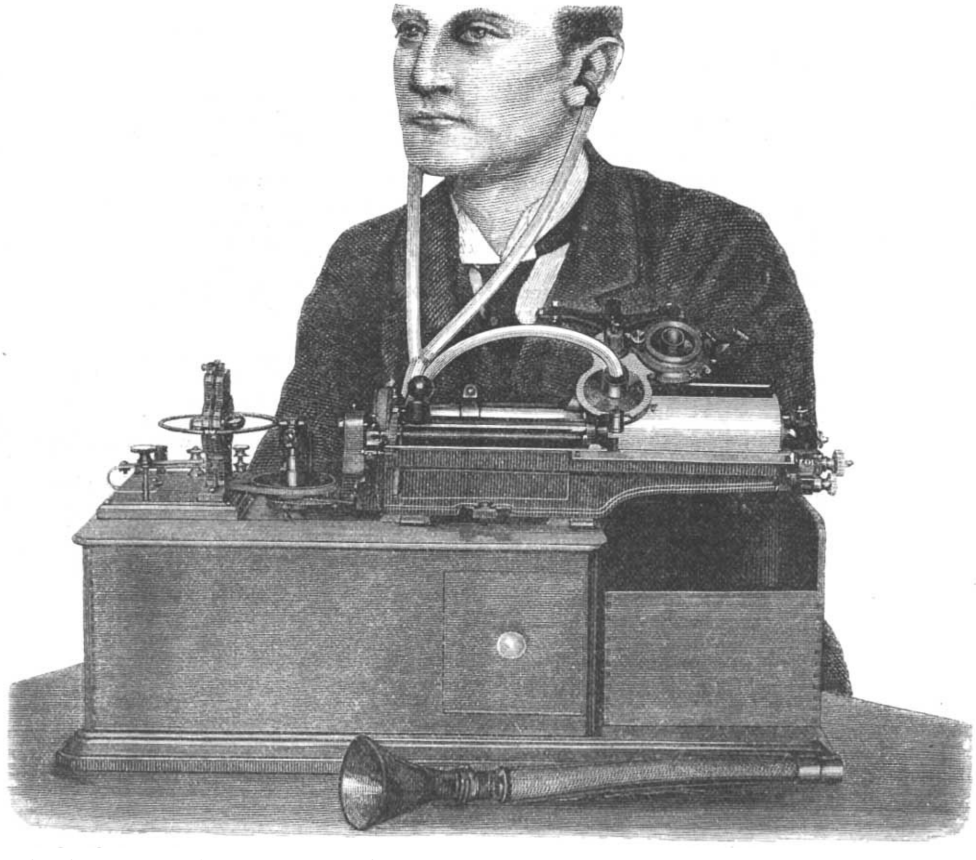
The records on the wax, on the other hand, have been recently reproduced over 3000 times.

As a good many of the specifications describing the new improvements are not yet made public, we are not at liberty to describe minutely the various parts of the instrument. We can, however, give the following outline of its leading features:—

(1) There is a brass cylinder on which the wax phonogram is placed.

(2) A rocking holding arm, which carries what is termed the "spectacle," containing the recording and reproducing diaphragms, and which by means of a traveller arm is made to engage two rotating screws—one called the feeding screw, very finely threaded, which causes it to travel slowly from left to right over the rapidly rotating phonogram, and thus trace out a long spiral on its surface; the other, a coarser reversely-threaded screw, which enables it to be moved back more rapidly opposite any required position on the phonogram. By means of a screw-head attached to a turning bar with an arrangement of cams, the rocking holding arm can be made to engage either the feeding or reversing screw, or else lift the diaphragm and its recording or reproducing needle entirely off the surface of the phonogram. These back and forward movements can be preferably made by a treadle attached to either the turning bar or rocking arm, leaving the hands free for other purposes.

(3) Another very practically useful adjunct consists of a projecting arm attached to the turning bar, by which the operator when desiring to stop and think what he is going to say next can completely disengage the diaphragm and and its accompanying recording needle from the surface of the wax; and if the pause is a long one, and he does not desire to waste his phonogram, he can reverse the movement of the diaphragm until it is opposite the point on the phonogram where he left off. By combinations of arrangements of this sort, all the actions of an ordinary writer, stopping to think, looking over, and even correcting what he has written, can be imitated.



Showing reproducing diaphragm in position, the operator listening through the tubes, and standing behind the instrument so as to allow it to be seen

(4) The arrangement by which a phonogram can be removed and another replaced, simply consists in having one of the centres on which the brass cylinder turns, attached to a movable arm.

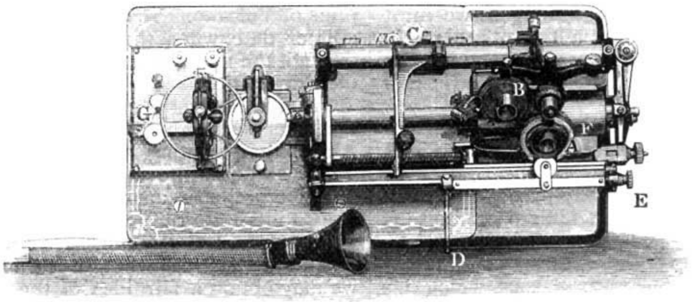
(5) Though, theoretically, one diaphragm could effect both record and reproduction, it is found that the same shape of needle or style is unsuited for both purposes. Consequently, there are two diaphragms, one a recorder and the other a reproducer.

The style of the recording diaphragm is made of such a shape as to be more of the nature of a graving tool, while that attached to the reproducing diaphragm is inclined at an angle to the surface of the wax, and glides over its indentations without destroying them. In front of the recording style is placed the cutting-out tool, whose function is somewhat analogous to the dibble of the gardener. It not only prepares a furrow in the wax in which the record can be made, but it also destroys any previous record. So that the making of a fresh record and the effacing of a previous one can proceed simultaneously.

The use of tubes to the ear raises a point about which a good deal of misapprehension appears to exist. The machine at present is not intended for reproducing sounds with their original intensity, but rather for the perfect reproduction of articulate speech and music. Many persons, therefore, on hearing the reproduction through the magnifying funnel, are disappointed to find the effect below their expectations. As soon, however, as they listen through the tubes, they are proportionately surprised at the loudness and the clearness of the sound and articulation. While for most practical purposes audition through the tubes is quite sufficient, Mr. Edison is, we understand, constructing a means by which the sounds can be greatly magnified. Even as it is, with the present funnel the reproduction can be heard very well throughout a large room. For example, at a lecture on November 10, before Harrow School, a perfect *mélange* of speaking, singing, and whistling, made by Colonel Gouraud on the spot, was plainly heard all over the lecture theatre, in which about 600 persons were present.

Other improvements comprise an electric motor and speed governor, by which the phonogram and the feeding screws can be rotated at a constant speed. As this electric motor is itself the subject of a separate patent, we are only at liberty to say that it is an electro-dynamic multipolar motor, in which a ring armature acts as a fly-wheel, and that it is adjustable to different speeds—a necessary point in order to preserve the same pitch where the rapidity of utterance is subject to variation. The circuiting of the motor and governor is ingeniously arranged so that the field of the armature can be opened without interfering with the field-magnet circuit, thus securing greater sensitiveness and an absence of sparking.

The phonograms themselves are divided into two sorts, office-grams and mailing-grams. The former are cylinders, capable at the present time of yielding from thirty to fifty surfaces for record, which number, as Mr. Edison says in a letter only received a few days ago, can now, by improved methods, be increased to two hundred. Obviously, however, such a cylinder would be an awkward affair to send by post. Mr. Edison has therefore met this want by constructing the mailing-gram, and though this may seem a small matter from a scientific point of view, yet we venture to prophesy that among all his many achievements there will be none to which he will look back with greater pride, or which are destined to work a greater revolution in the history of the world than this apparently simple little mailing-gram. To say that it is capable of being posted, and reproduced at the other end without injury to the record, may perhaps give some idea of its practical value.



Instrument turned over so as to present a top view with recording diaphragm in position. A, recording diaphragm; B, reproducing diaphragm; C, rocking holding arm; D, bar for arresting record; E, turning bar; F, wax cylindrical phonogram; G, electric speed governor.

Regarding the way in which all this is accomplished, it is needless to say anything, except that the device bears the true stamp of genius, viz. simplicity. This portability of the phonograms is, in fact, one of the salient features by which the phonograph of 1888 stands out in marked contrast to the imperfect machine of 1878, and this improvement, in combination with the greater perfection and permanence of the record, at once raises it from the level of a pretty scientific toy or curiosity to one of immediate utility.

The practical working of the instrument, which has been greatly improved even upon what it was at the meeting of the British Association at Bath this year, may be gathered from the fact that Colonel Gouraud dictates all his correspondence through it, speaks to it in different languages, applies every conceivable test to try its powers, and with results which not only astonish him and everybody else, but even the inventor himself.

The purposes to which such an instrument can be applied—scientific, commercial, domestic, artistic, military—seem countless. The dreams which were indulged in when the phonograph of 1878 appeared, can now be realized; and we owe to Mr. Edison another substantial addition to the long list of direct results of scientific labour achieved during the present century.

FURTHER NOTES ON THE LATE ERUPTION AT VULCANO ISLAND.

MY friend Signor Gaetano Platania, who accompanied me on my trip through the Lipari Islands in June 1887, and stayed some days with me at Vulcano, has undertaken the task of describing that interesting event and the subsequent phenomena. He has very kindly forwarded me specimens of the ejectamenta, and to him I must express my thanks. He being already well acquainted with the products of that volcano, his observations will be of considerable value when published.

The first specimen submitted to me is that of the so-called bombs, common in other eruptions that have taken place from the present active crater of Vulcano. It is undoubtedly the *essential* ejectamenta, although included in the paste is much fragmentary *accessory* material. These so-called bombs are irregular polygonal masses of an obsidian-like material on the outside; the surfaces are traversed by a number of clefts or fissures V-shaped in section, which at their bottom and the deeper parts of their sides are seen to be composed of a spongy glass or even pumice. Their mode of formation is no doubt as follows:—The glassy magma from former loss of heat has become so viscous that the escape of vapours from the underlying magma is arrested until the tension rises, and the superincumbent pasty, almost solid, mass is broken up and ejected. This ejection has been preceded by some expansion and cracking, together with some cooling along the cracks, so that the blocks have partly consolidated as pumiceous obsidian, but when relieved from these conditions by ejection, the hotter material